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15. Abstract

Photographic and digital imagery received from ERTS-1 was analyzed and evaluated as to its usefulness for the assessment of agricultural and forest land resources.

Black and white, and color composite imagery provided spectral and spatial data, which, when they were matched with temporal land information, provided the basis for a semidetailed land use and forest site evaluation chartography.

Color composite photographs have provided some information on the status of irrigation of agricultural lands.

Computer processed digital imagery was successfully used for detailed crop classification and semidetailed soil evaluation.

The results and techniques of this investigation are applicaple to ecological and geological conditions similar to those prevailing in the Eastern Mediterranean.

APPLICATION OF ERTS-1 IMAGERY TO LAND USE, FOREST DENSITY AND SOIL INVESTIGATIONS IN GREECE

By

N. J. Yassoglou, E. Skordalakis and A. Koutalos.

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PREFACE

During the Mycenean and Classical Eras, the inhabitants of Greece had a remarkable knowledge of the properties and of the potentialities of their land resources. There is ample evidence that the utilization of land, during those times, was based on quite sophisticated systems securing its conservation. From the time of the Roman Conquest of the country up to the present time, little attention was given to land resources. Thus the lack of data is a serious hindrance to the elaboration of modern land development projects.

The objectives of this investigation were to determine whether remote sensing data obtained by satellites could be used in recognizing, evaluating and mapping land features and resources of particular interest to Agriculture and Forestry.

The emphasis of this investigation was placed on the study of land use patterns, the evaluation of ecological sites, the estimation of forest density, the study of soil properties and the mapping of the recognizeable soil classes.

The data which were analyzed in this investigation were obtained by ERTS-1 on the 2nd of August, 1972.

Two frames covering sites of Central and Southeastern Greece were analyzed both in Greece and at LARS of Purdue University in the U.S.A.

Gray scale classes on the black and white photographic imagery were assigned to land use patterns. Ecological sites were recognized on the false color composite imagery.

Digital data were analyzed by computer using the LARSYSAA program. Spectral classes were assigned to detailed land use features and semidetailed soil units.

The results of this investigation show that remote sensing data, obtained through satellites, can be used for the recognition and mapping of land features.

The conclusions of this investigation are particulary important to developing countries, where surveys and information on land resources are limited. In these cases a quick inexpensive and relatively realiable evaluation of agricultural and forest resources can be achieved both on a permanent and on a temporal basis.

METHODS AND MATERIALS

ERTS-1 was successfully launched on July 23,1972 and provided photographic and digital imagery of selected areas of Greece.

Two frames covering the Athens-Delphi and Eastern Peloponnese provinces in the south eastern part of the country were studied in this investigation. The studied remote sensing information was recorded on the 2nd of August, 1972. The local time was about 10.30 a. m.

Ground truth information was collected prior to the launching of ERTS-1. Data affected by temporal variations were collected on the date that the satellite obtained information over Greece.

Black and white photographic imagery was studied first and gray scale classes were related to land use features and to forest density.

False color composite photographs were used next, to further separate land use features,evaluate agricultural and forest sites and classify soils into broad categories.

Digital imagery was processed at LARS (Fu and Langrebe 1969) using the LARSYSAA computer program to determine detailed land use classes, map crop distributions and to recognize salinity and drainage conditions of the soil in selected small areas.

Land feature maps, prepared from photographic and digital imagery, were checked in the field and their accuracy was tested. Thus improved relationships between ground truth and spectral information were achieved.

RESULTS AND DISCUSSION

Analysis of photographic Imagery

Multispectral scanner and RBV photographic imagery was analyzed and the following land features were recognized.

Land Use Patterns.

The recognition of the land use patterns was based on the study of the gray scale classes and of the spatial characteristics of the RBV and MSS black and white and of the false color composite images.

Vegetation was best separated from bare land on the RBV channel 2 and MSS channel 6 imagery.

The photographs were studied with use of a magnifying viewer and a stereoscope. Eight gray scale classes were visually recognized on the RBV channel 2 black and white transparencies. Detailed ground truth data were used for

the assignment of land features to each gray scale class.

On the basis of spectral and spatial information derive from the ERTS-1 photographic imagery, a land classification scheme was developed as shown in table 1.

Table 1 shows that, with the exception of gray scale 0, each gray scale class corresponds to more than one land use class. From the practical point of view it is a necessary that these groups of land use features be separated. This separation was achieved by making use of the existing geographical and geomorphological information and by the use of the false color composite pictures as follows :

Water corresponds to the darkest gray scale class on the black and white photographic imagery.

The next darkest, class 1 covers well irrigated annual and perennial agricultural crops as well as dense fir and austrian pine forest stands.

The agricultural crops can be separated from the forest by their geographical distribution. Well irrigated crops are grown on the flat bottom land, while fir and austrian pine are grown on ragged mountainous terrain, at high elevations. These two land forms can be easily recognized and separated on the 1:1,000,000 photographic imagery by their characteristic texture as it is discribed in the discussion of the soils.

On the false color composites the irrigated agricultural crops are bright red, while the fir austrian pine forests are dark red. Thus they can easily be separated from each other.

In gray scale class 2, dense halepo pine and hardwood forests could not be separated on the black and white picture from marginally irrigated orchards and other crops. It is known, however, that halepo pine grows mainly along the coastal areas of Southern Greece, at an elevation not exceeding the 800 meters. In contrast, hardwood species from forest stands in the central part of the country and at elevations usually exceeding the 500 meters. Thus in most cases, with few exceptions, halepo pine can be separated from the deciduous forests. In false color composites the deciduous forest shows a brighter red color than the pine forest. This subject will be elaborated on in the study of ecological sites.

Orchards are found in Greece mainly on recent alluvial or quaternary deposits, which are easily delineated on the 1:1,000,000 scale space photograph. Small localized areas covered with orchards are also found on some mountain slopes along with pine and deciduous forest. These can not be separated from each other on the 1:1,000,000 photograph.

In gray scale class 3 the separation of thin pine forests from thin deciduous forests and shrubs presents similar problems, which can be also solved by considering the geographical distribution of the species.

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Table 1. Classification of land features based on ERTS-1 photographic imagery

Gray scale class	Appearance in color composite photograph	Geographic and spatial characteristics	Land use class
o	Dark blue	Sea, lake, river	Water
1	Bright red	Flat land, geometrical shapes	Well irrigated agriculture
	Dark red	High mountains ragged terrain	Fir Austrian pine forest
2	Reddish brown-pink	Coastal slopes	Dense Halepo pine forest
	Bright red	Inland mountains	Dense hd-wood forest
	Red to pink	Flat land, fragmented fields	Marginally irrigated agriculture
3	Mottled (red, brown, yellow, purple)	Coastal slopes	Thin Halepo pine, shrubs
		Inland mountains	Thin hardwoods, shrubs
4	Mottled, mostly reddish brown and yellowish	Ragged terrain	Shrubs, pines, olive trees, bare soil and rocks intermixed
5	Yellowish white to orange	Flat or gently sloping land	Non irrigated olive groves, vineyards with some pines and shrubs
6	White, yellowish white, bluish white.	Flat or gently sloping land	Non irrigated winter crops, bare soil
		Ragged terrain	Thin shrubs and rocks
7	White to blue	Ragged mountain slopes	Bare wasteland
		Residential patterns	Cities and towns

This class, due to the irregular mixing of thin forest stands with shrubs, bare soil and some dense stands, has a characteristic texture consisting of small areas of different brightness.

Gray scale class 4 corresponds to degraded sloping land, which due to severe grazing and lumbering, has lost a great part of its vegetational cover. Consequently intensive erosion has exposed the bedrock on a large portion of surface of the land. Due to the high reflectivity of the bare soil and exposed bedrock, the pattern of this class is brighter than that of the previous class. The texture, however, is the same in both classes.

Olive groves and vineyards in Greece are in most cases non irrigated crops. Bare soil represents about 50% of the total area and it contributes significantly to the reflectivity of the land surface. Due to the dry climate and the lack of irrigation, the plants suffer during the summer months from moisture stress and thus they absorb less visible light. Consequently this class is only slightly darker than the bare soil. Geomorphologically, these crops grow mostly in Southern Greece on quaternary deposits and on the slopes of tertiary formations.

The separation of this class from the following class of winter crops on the black and white photographs is difficult.

On the false color composite, class 5 shows a yellowish orange tinge, thus it can be separated from the yellowish white colored class 6. The separation of class 5 from class 4 is relatively easy because of the difference in the brightness of the surface.

Due to the fragmentation of the cultivated areas and the brightening effect of the large portion of the bare soil, the separation of vineyards from the olive groves is not feasible on the 1:1,000,000 space photographs.

Gray scale class 6 is brighter than the previous classes, because during the period of August, when the data were obtained by ERTS-1, the respective land surfaces consisted either of bare soil or of harvested winter crops, principally wheat and barley.

Class 6 is not easily recognized from class 7 in the gray scale. Class 7, however, is mainly found on mountainous terrain while class 6 is located on the quaternary and tertiary deposits of lower lands.

In the false color composite photograph class 6 is predominantly white to yellowish white, with some bluish spots corresponding to cultivated bare soils.

Class 7 corresponds mainly to bare soil and rock outcrops located on the eroded mountainous land and to residential areas, which, in Greece, usually have sparse vegetation.

The vegetation of the lands of class 7 consists of sparse small shurbs of predominantly xerophytic species. Thus the reflection pattern is determinated by the soil and bedrock surface.

Class 7 is the brightest of all the recognized by naked eye gray scale classes. Its separation, however, from class 6 is difficult on the black and white photograph. On the false color composite photograph, however, it has a dinstinct bluish white color peculiar to this class.

Figures 1 and 2 show land use map of Central and Eastern Peloponnese made on the basis of ERTS- 1 photographic imagery.

The minimum size of the area, which could be classified and mapped on the 1:1,000,000 scale photographic imagery was about 500 hectars.

Ecological Site Evaluation

The subhumid and the semi-arid climatic zones cover the greatest part of Greece's productive lands. Therefore, the water supplying power of the soil during the dry months is a critical and in many cases the limiting factor for the growth of the plants.

The conditions which affect the water supplying power of the soil in the agricultural lands are the natural soil drainage and the applied irrigation water.

In the forest and range lands these conditions are the local climate, the geology, the soil depth and texture, the slope of the land and its geographical orientation (aspect).

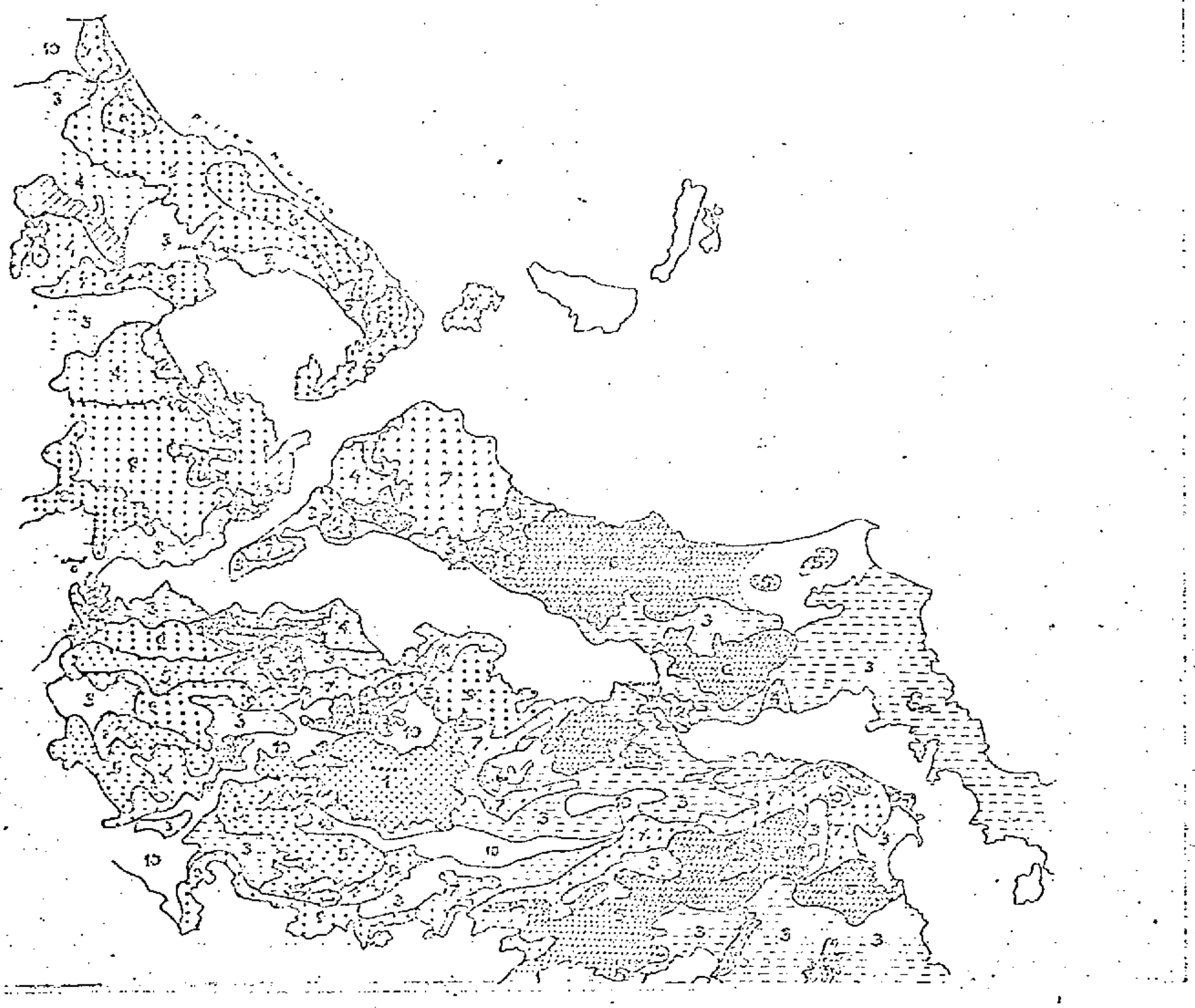
The tension of the soil moisture affects the structural characteristics and the leaf area of the plants. These parameters determine the reflectivity of the vegetational cover of the soil (Mayers 1970). Consequently the reflectivity of the vegetation can be used as a measure of the effectiveness of irrigation in the agricultural lands and of the site quality of the forest and range lands.

The false color composite space photographs show a range of red colors corresponding to vegetation. A close inspection of the areas of various degrees of brightness of the red color on the photograph indicated the possibility of assigning them to respective site classes. (Orme et al. 1971, Krumpe et al. 1971 and Colwell 1972).

Ground truth data collected through extensive field observations confirmed the above hypothesis.

It was found on high elevations, where the climate is humid to subhumid, that the dominant factor which influences the water supplying power of the soil is its depth. In these areas the bright color corresponds to vegetation grown on deep soil, while less bright red color is found on sites with shallower soils.

The deep residual soils are normally found in Greece on mica schist and on



.1. Land use map of Central Greece

ell irrigated agricultural crops. 2. Marginally irrigated crops,vineyards, e trees, orchards. 3. Non irrigated agricultural crops,olive groves, yards,annual crops. 4. Non irrigated winter crops and bare soil.5. Fir austrian pine 6. Dense halepo pine. 7. Thin halepo pine. 8. Dense deciduous st. 9. Thin deciduous forest, shrubs, scattered olive trees. 10. Shrubs sely covered wild land and urban areas.

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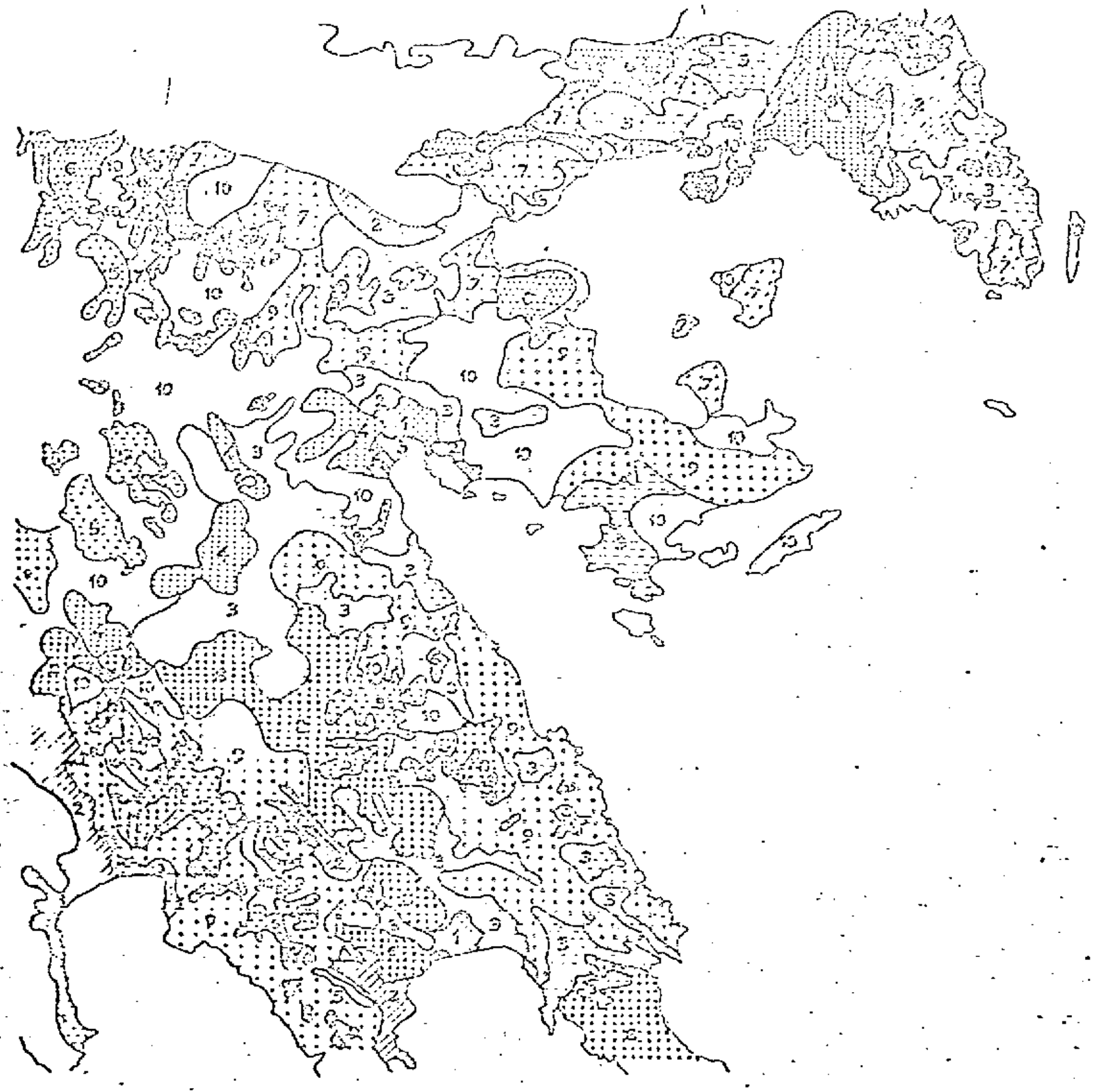

Fig. 2. Land use map of Eastern Peloponnese, Greece.

1. Well irrigated agricultural crops. 2.Marginally irrigated crops,vineyards, olive trees,orchards. 3.Non irrigated agricultural crops,olive groves, vineyards,annual crops. 4.Non irrigated winter crops and bare soil. 5.Fir and austrian pine. 6.Dense halepo pine. 7.Thin halepo pine. 8.Dense deciduous forest. 9.Thin deciduous forest,shrubs,scattered olive trees. 10.Shrubs sparsely covered wild land and urban areas.

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interbeded sandstone, siltstone and shale. Thus, the colors on the photograph can be correlated with the geological substratum. Exceptions to this observation are few, confined to areas of small slope, where deep soils form also on other parent materials.

On the lower lands and hills, where deep soils are developed on quaternary and tertiary deposits, the dominant site factor is the distribution of the rainfall throughout the year and not the soil depth. A site evaluation map was made on the basis of the above observations. The following site classes were recognized and mapped in Central Greece and they are shown in figure 3.

Site 1 corresponds to well irrigated agricultural lands. The bright red colors in the plain of Kopais and in the alluvial fan of Lamia are characteristic of the well irrigated summer crops, in this site.

Site 2 includes agricultural lands, where irrigation is localized and water is applied in limited quantities.

The forest and range lands were classified into three site classes on the basis of the visually estimated brightness of the red color.

Site class 3, shown in the map of Central Greece, has bright red color and it includes lands with relatively deep soil, which has adequate water storage capacity. These lands are located in the humid zones of the mountains. A typical example of these lands are the eastern slopes of Pilion Mountain. The forest species have a high rate of growth, the reforestation is easy and returns of investments are considered satisfactory.

Site 4 shows on the photograph a less bright red color than class 3. The lands of this class are located: a) on humid mountainous regions with soils of moderate depths and b) on subhumid lowlands and hills with soils of adequate depth. In both cases the water supply power of the soil during the summer is relatively low. Thus, the productivity of the lands of site 4 is moderate.

Site class 5 shows a reddish brown color on the photograph. The lands of this class are characterized by a summer drought and/or shallow soil. The growth rate of the forest species is low, reforestation success is limited and pastures are dry during the summer and fall months. Investments for the development of these lands will produce limited of doubtfull returns.

Site class 6 is exceptionally dark on the color composite photograph. Ground truth data show that the area consists of broken halepo pine stands, which have suffered severe resin extraction treatments. The cleared areas are used for dry farming and for grazing.

The foliage of the pine trees is yellowish due to the large scars that have been made on their trunks. Thus, the dark color in the photograph may be

Fig. 3. Site evaluation map of Central Greece.

attributed to the stress of the trees.

The areas 7,8 and 9 in figure 3 correspond to olive groves and vineyards, nonirrigated winter crops and bare soil and rock outcrops respectively, as it was described in the land use analysis.

The site classification map, which was made on the basis of false color composite 1:1,000,000 scale space photograph, can be used for the planning of the forest and range development of Greece on a more solid and scientific basis than it has been done so far. The results of this investigation could possibly be extended to other countries with similar climatic conditions.

Soil Features.

The following classes of soil groups have been recognized on the black and white and on the color composite space photographs.

Severely eroded mountain soils.

Mountainous lands have lost most of their soil and the bedrock is exposed on the largest part of the surface. Due to the absence of soil, deep enough to support vegetation, these lands are bright on the black and white photograph and bluish white on the false color composite. Since their soil is considered practically unproductive, the knowledge of its extent and distribution in the country is necessary for the planning of resource development. The space photographs provide a quick, inexpensive and relatively accurate estimate of these soils. Class 10 in the land use map of figures 1 and 2 represents this group of soils.

Saline soils.

Most of the saline soils of Greece are associated with the imperfectly and poorly drained soils of the coastal plains. Due to salt limitations, the vegetation is poor and in the summer months is either dry or under stress. The color of the soil is dark, except in small spots, where due to the precipitation of fine salt crystallites, is almost white.

Since the saline soils are localized in relatively small areas, where they are mixed with non saline soils, the 1:1,000,000 scale space photograph is not very convenient for their indentification in the coastal plains of Greece.

Black and white photographs produced by the computer at LARS from digital

MSS data at x 16 magnification were used for the indentification of the coastal saline soils of Greece, as it is shown in figure 4.

The separation was made by comparing the computer produced photographs of the green channel with those of the infrared channel.

A test area was selected in the Skala coastal plain south of Sparta in Peloponnese, where detailed ground truth information was collected.

In August, irrigated crops, wet land and saline soils are shown dark on the green channel photographs. Thus, they cannot be separated. On the photograph of the infrared channels, however, irrigated crops and vegetation on wet land are highly reflective and cover light areas in the photograph. In contrast the saline soils are dark both in the green and in the infrared band. Due to moisture stress, the reflectivity of the vegetation in also low and contributes to the darkness of salt affected areas (Mayers 1970, Causman 1971).

Saline soils can be separated from the non saline bare soils of the area by comparing the above photographs. Bare non saline soils are less reflective than the saline soils in the infrared band. Thus, they are shown as light spots in the green channel and dark in infrared channel, while as it was indicated above the saline soils appear dark in both channels.

Wet soils.

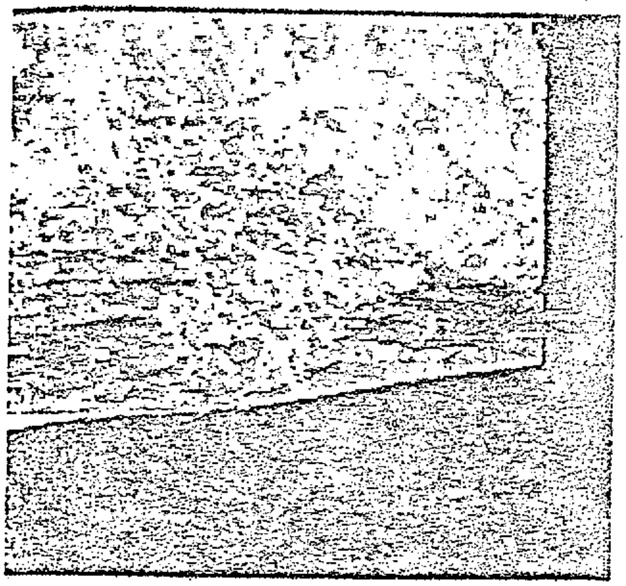
Poorly drained soils are generally darker than well drained soils. Their differences in the reflectivity were not great enough to allow a direct soil drainage classification in the 1:1,000,000 scale photographs. Temporal differences may be a useful tool, but at present such data are lacking.

The recognition of poorly drained soils and wet lands in a semiarid and subhumic country, such as Greece, can be based on the reflectance of the vegetation.

As it was discussed in the land use and the site evaluation sections of this report, a high water supply capability of the soil causes a sharp decrease in the reflectivity of the vegetation in the visible bands and an increase in the infrared bands.

The reflectivity of the plant leaves is known to decrease in all bands with increasing water content (Mayer 1970). The increase in the brightness of the red color in the false color composite photographs, which was observed on sites with adequate supply of soil water, can be explained by the denser vegetational cover in these areas.

In areas where soil water is a limiting factor for plant growth, an increase



a

b

Fig. 4 Computer proccessed digital MSS imagery of Scala, Plain, Sparta, Greece.

a. Green band showing wet and saline soils.

b. Infrared band showing the saline soils.

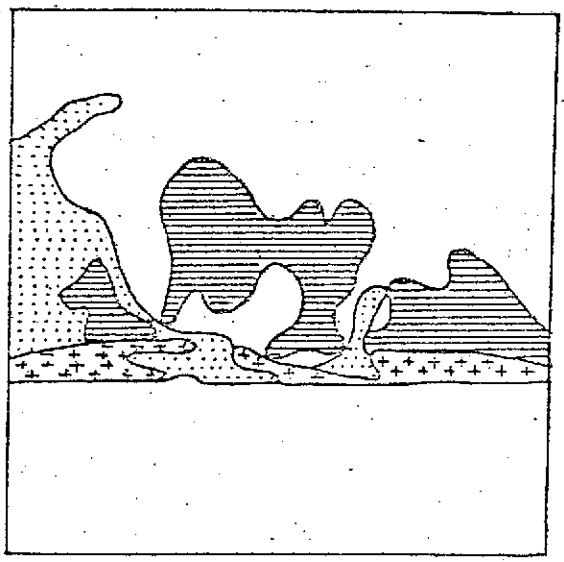


Fig. 4 Soil map of Scala, Plain, Sparta, Greece.

Saline soils.

Poorly drained soils.

Sand dunes

in soil moisture increases the number and the size of the plants and consequently the ratio of vegetation to bare soil becomes greater. Thus, an enhancement of the reflectivity in the near infrared band is observed in wet soils during the dry months of the year.

In the false color additive photographs, taken over Greece during the month of August, poorly drained soils and well irrigated soils show a bright red color. They can be separated, however, from each other from their spatial signatures. Wet lands are idle and no geometrically shaped fields can be observed on them.

Geomorphological features of the soil.

Important soil characteristics such as parent material, relief, erosion, drainage, stage of development and productivity are related to geomorphology.

The black and white and false color composit photographs can be used for the classification of the geomorphological features. The best imagery for this purpose was the infrared black and white and the false color composite.

The following three classes, which bear importance to soils, were recognized in the 1:1,000,000 scale imagery:
(1) Mountain slopes.
(2) Gently sloping tertiary deposits.
(3) Flat recent alluvial plains.

The above classes were recognized from their characteristic textures in the photographs. The mountainous regions characterized by deep and large valleys, gullies and faults were easily recognized. The separation of the tertiary deposits from the recent alluvial plains was made by the use of microscopic stereonscope. The tertiary deposits are located on higher elevations than the recent alluvial deposits. Erosion has caused, on the tertiary deposits, the formation of a network of gullies, which vary in size and orientation. This network dissects the tertiary deposits, and produces a characteristic texture, which in many cases can be seen on the 1:1,000,000 scale photograph by the use of magnifying stereoscope. The recent alluvial deposits are flat and thus lack the erosional paterns of the tertiary deposits.

The above three geomorphological classes can be used in reconnaissance soil classification and mapping.

On the mountain slopes form residual soils characterized by erosion hazards, depth limitations and low productivity. The tertiary deposits are the parent material of deep soils with well developed horizons, moderately eroded and in many cases calcareous. These soils are used for dry farming. Their agricultural value is moderate to low.

The recent alluvial soils are young in age, calcareous and they lack in well developed horizons. They are the best suited soils for intensive agriculture.

The ERTS-1 photographic imagery was used for the correction of the boundaries of soils developed on tertiary and recent alluvial in the 1:1,000,000 scale soil map of Greece.

Analysis of Digital Imagery

Digital data of frames: ERTS-1010-08375 (Eastern Peloponnese) and ERTS-1010-08373 (Central Greece) were reformated and processed by the IBM system/360 Model 67 Computer at LARS of Purdue University. The LARSPLAY and the LARSYSAA programs (6) were used for the processing of the data.

Feature vectors were analyzed and classified into 15 spectral classes by the LARSYSAA program. The computer was instructed to print maps of the above two provinces of Greece by assigning alphanumeric symbols to each of the classes.

A more detailed study of the fifteen classes was conducted in the Kopais plain, where sufficient ground truth data were collected during the month of August of 1972.

The Kopais plain is located about 70 miles north west of Athens. It consists of a drained lake bed, which is primarily used for irrigated agriculture. The plain is surrounded by hills consisting of limestone rock outcrops with sparse vegetation and of tertiary and quaternary deposits, which have areas covered by shrubs and trees, intermixed with fields used for nonirrigated winter crops.

Spectral Classes.

The characteristics of the spectral classes of the Kopais plain are given in table 2. The modality of the histograms for each class and channel is shown in table 3. The classes can be characterized as unimodal except for the classes 4 and 14, which could be separated into two subclasses.

Table 2. Relative reflectivity of the spectral classes of the Kopais Plain

Spectral class	Total Energy λ (μ)	% Energy at λ (μ) 0,50 - 0,70	% Energy at λ (μ) 0,70 - 1,10	Ratio % 0,50 - 0,70 / % 0,70 - 1,10
1/15	201.31	54.85	45.15	1.215
2/15	167.47	32.96	67.03	0.492
3/15	155.26	37.35	62.64	0.596
4/15	163.51	46.58	53.41	0.872
5/15	145.45	44.11	55.88	0.787
6/15	168.78	54.23	45.77	1.185
7/15	152.31	53.56	46.44	1.153
8/15	138.09	53.97	46.02	1.173
9/15	147.57	50.10	49.89	1.000
10/15	136.86	39.24	60.75	0.645
11/15	134.36	49.39	50.60	0.976
12/15	126.07	42.42	57.57	0.737
13/15	123.82	51.35	48.64	1.056
14/15	109.14	52.54	47.45	1.107
15/15	63.29	75.25	24.74	3.041

Table 3. Modality of the histograms of spectral classes.

Spectral class	MSS Bands 4	5	6	7
1/15	unimodal	bimodal	unimodal	unimodal
2/15	uni -	uni -	bi -	uni -
3/15	uni -	uni -	bi -	uni -
4/15	uni -	bi -	uni -	bi -
5/15	uni -	uni -	uni -	uni -
6/15	uni -	uni -	uni -	uni -
7/15	uni -	uni -	uni -	uni -
8/15	uni -	uni -	uni -	uni -
9/15	uni -	uni -	uni -	uni -
10/15	uni -	uni -	uni -	uni -
11/15	uni -	bi -	uni -	uni -
12/15	uni -	uni -	uni -	uni -
13/15	uni -	bi -	uni -	uni -
14/15	uni -	bi -	uni -	uni -
15/15	uni -	uni -	bi -	uni -

Land Use Classes.

On the basis of ground truth data and their spatial and spectral characteristics the fifteen classes were assigned to eight land use classes as it is shown in table 4.

Table 4. Correspondence of spectral classes to land use classes.

Land Use Classes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Corn										+		+			
2. Wheat							+								
3. Alfalfa		+													
4. Trees-shrubs									+		+		+	+	
5. Cotton			+												
6. Unknown				+	+			+							
7. Soil						+		+							
8. Eroded Soil	+														
9. Water															+

Table 4 shows that in many cases more than one spectral classes had to be grouped into one land use class. This was necessary because land use subclasses were not spatially separable and it was to some extent, justified by the proximity of the spectral ratios of the grouped spectral classes shown in table 2.

The modality of the land use classes was tested from the histograms, which were calculated by the statistics processor of the LARSYSAA program. The results of these calculations are shown in figure 5.

The most reflective spectral class 1 was assigned to soils with light clored surface. The parent material of the drained lacustrine soil is a whitish marl. Upon oxidation of the thin organic surface layer and deep

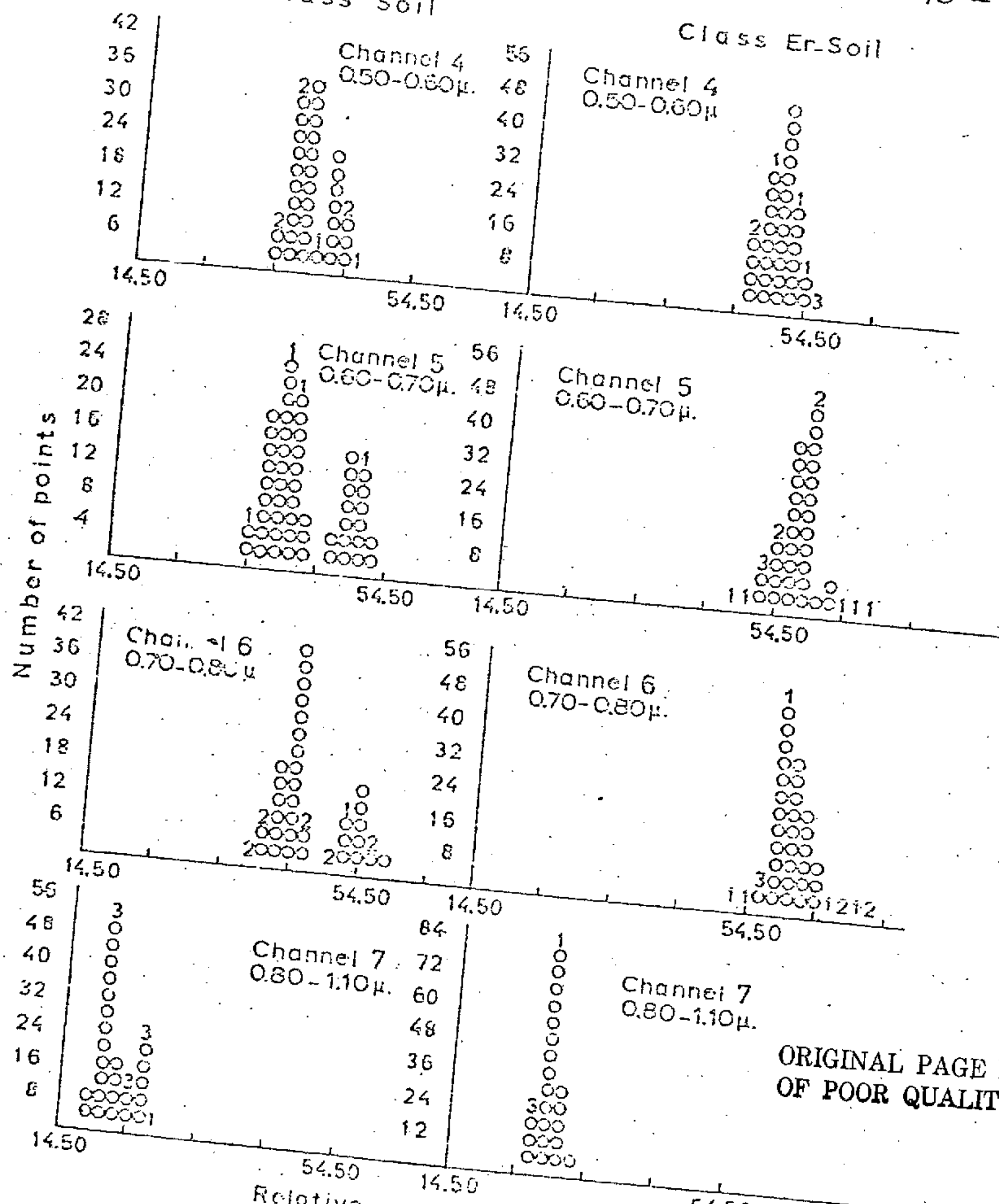


Fig. 5 Spectral histograms of land use classes

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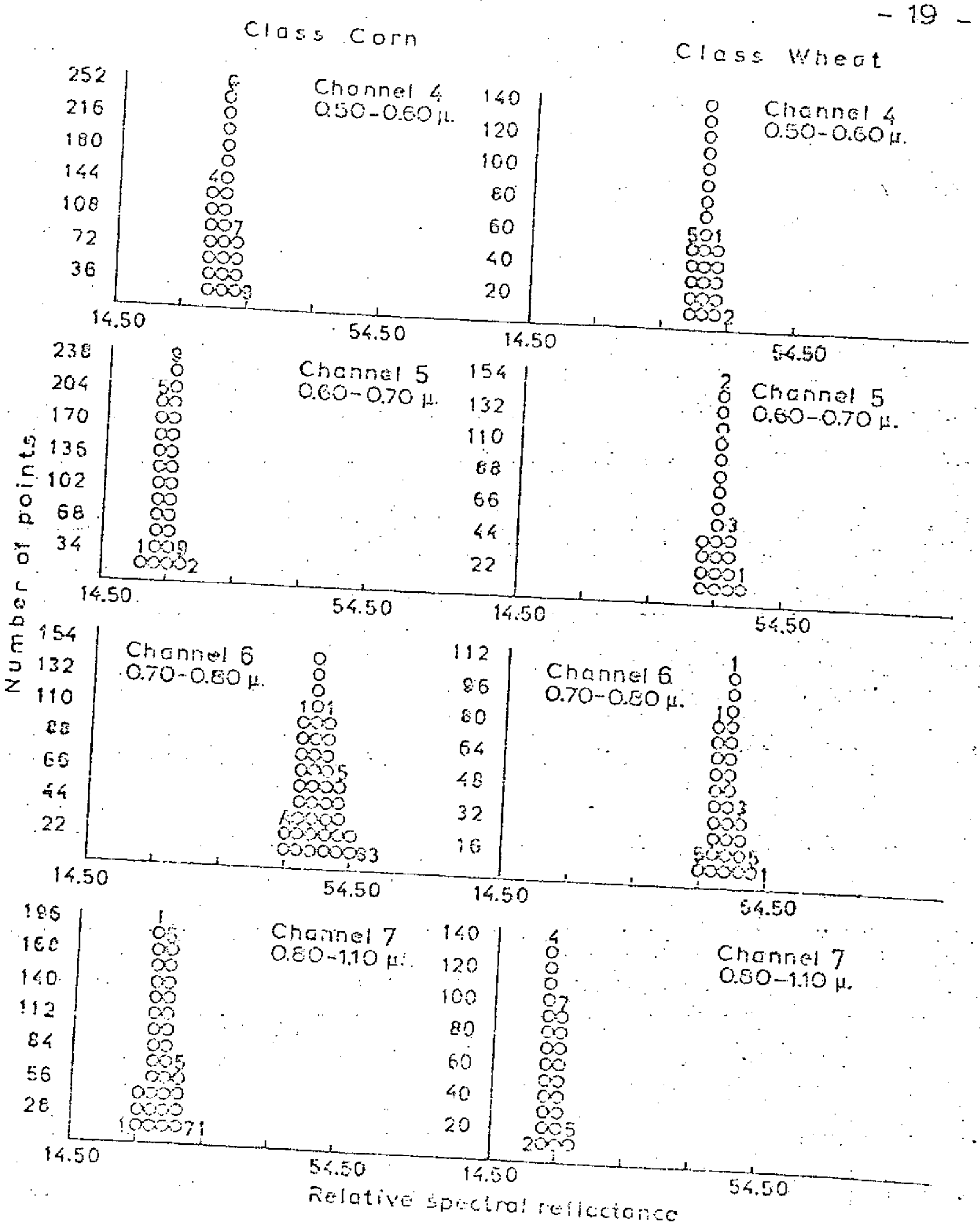

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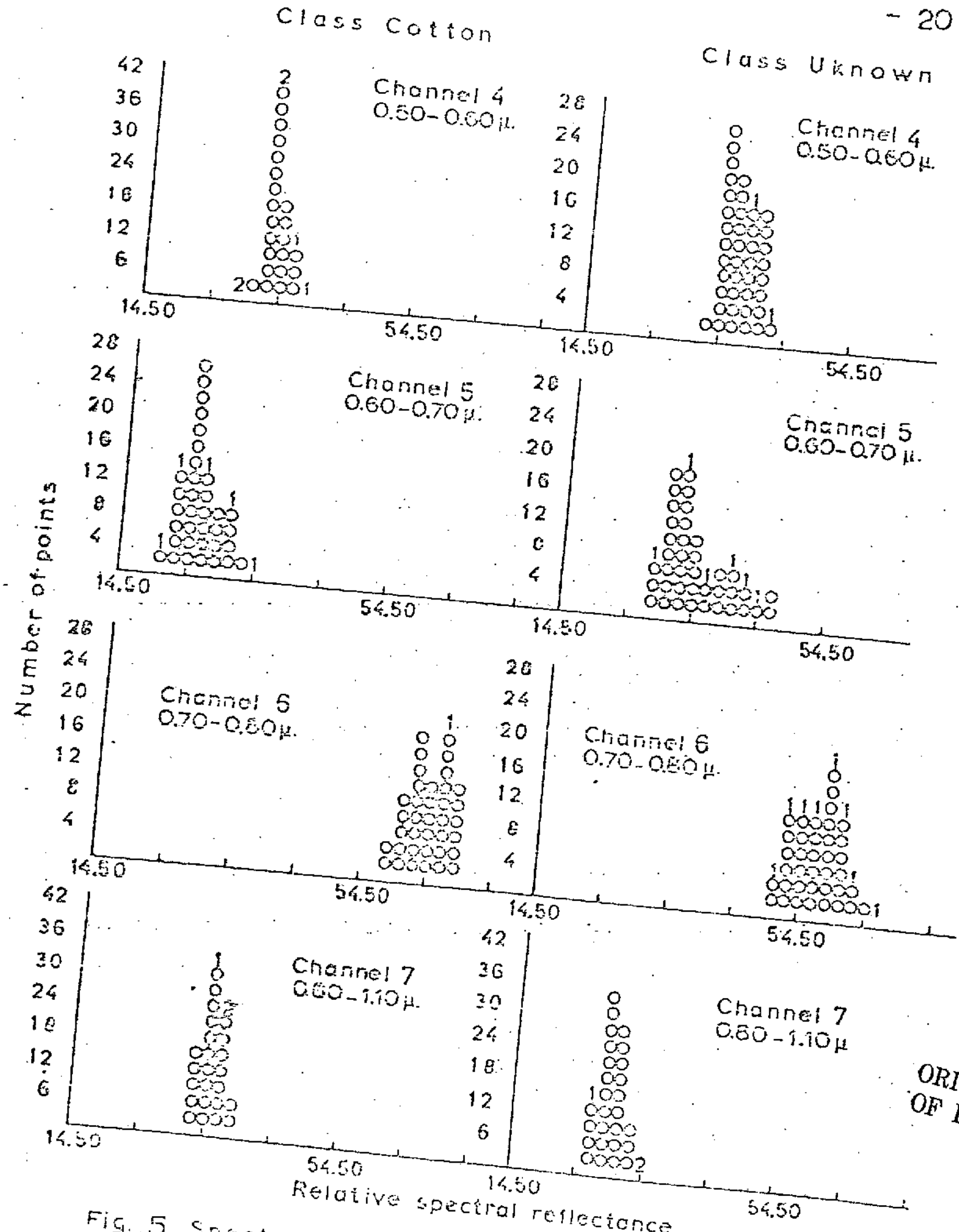

Fig. 5 Spectral histograms of land use classes.

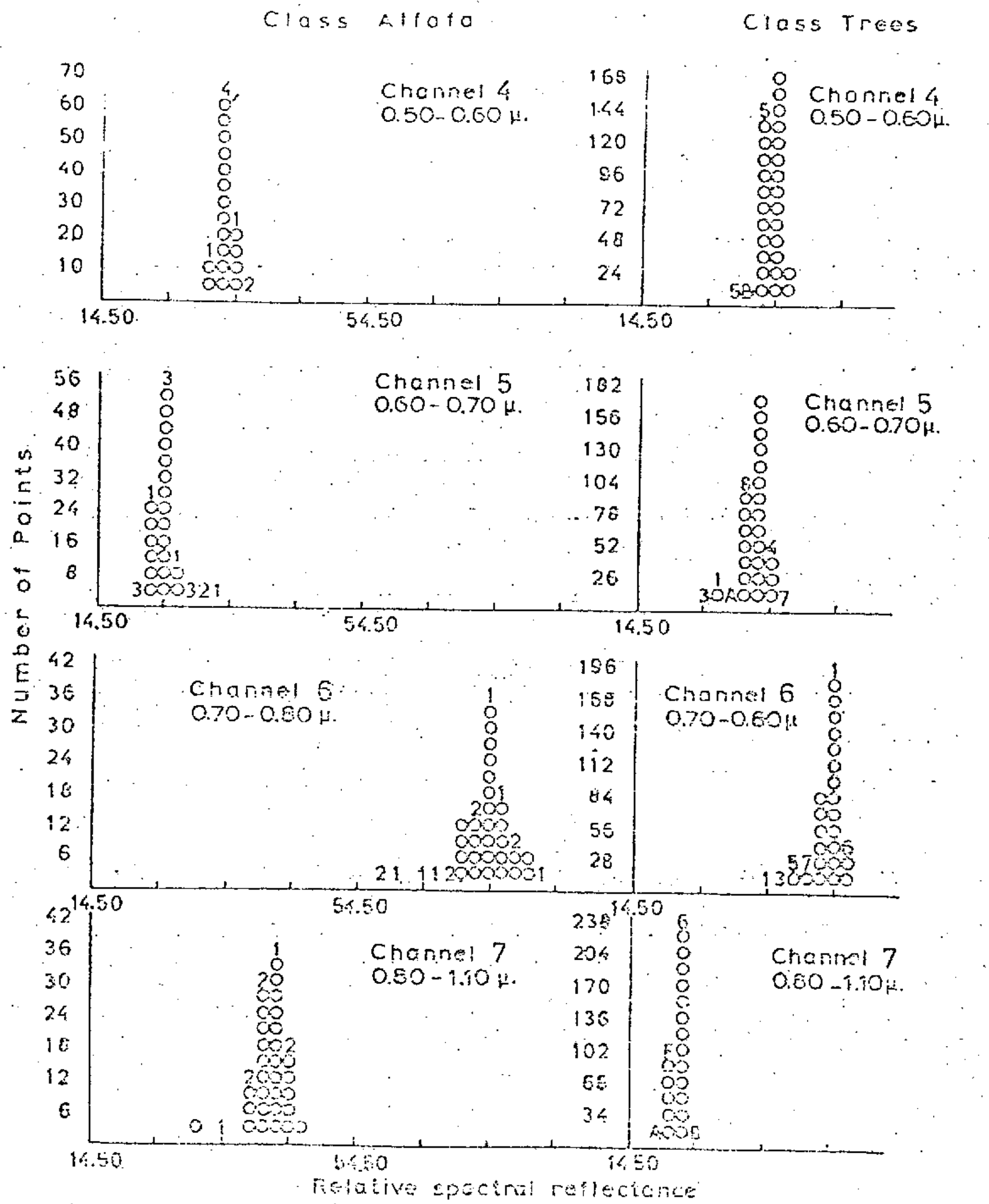

Fig. 5 Spectral histograms of land use classes.

ploughing, the marl was brought to the surface of the soil in many locations. This soil surface has the highest total reflectivity of all the other surfaces in the studied area. The reflected energy in the visible part of the spectrum is greater than in the infrared due to the lack of vegetational cover. Eroded alfisols having their red colored Bt horizon exposed on the surface belong also to the spectral class 1.

This land use class named "eroded soils", is found both of the marly bottom land and on the eroded slopes of the tertiary deposits.

The spectral classes 6 and 8 were assigned to the bare soil surface. From these two classes the first has higher total reflectivity than the second one. Their spectral ratios, however, are about the same. The histograms in figure 5 also indicate that two bare soil surfaces can be recognized.

Indeed, ground truth data have shown that the brighter spectral class 6 should be assigned to flat bare soil surfaces of the bottomland in areas where the marly parent material has not been exposed. Class 8 should be assigned to the rocky surfaces of the surrounding the bottomland hills. These hills have the limestone bedrock exposed on the greater part of their sloping surfaces. The vegetation is sparse and it was mostly dry during the recording of the spectral data by ERTS-1.

The roughness of the surface and the presence of dry vegetation could possibly explain the lower reflectivity of spectral class 8 as compared to spectral class 6.

The recognition, separation and mapping of the above three classes of soil can be regarded as a significant achievement toward the assessment of the productivity of the studied area. Thus, spectral class 6 corresponds to highly productive soil and spectral class 1 corresponds to unproductive soil.

Spectral class 7 was assigned to wheat fields. In August, at the time that the data were recorded by ERTS-1, the wheat fields had been harvested and only, short dry straw remained on the ground. Thus, bare soil constituted a large portion of the reflecting surface. Accordingly the spectral data (table 2) of class 7 do not diviate singnificantly from those of the classes 6 and 8, which were assigned to bare soil. Due to the uniform distribution and the minuteness of the soil and straw surfaces, the whole reflecting surface appears uniform. For this reason the respective histograms are narrow.

Spectral classes 2 and 3 were assigned to alfalfa and cotton respectively. Both classes are characterized by low spectral ratios. Both crops were irrigated and thus were highly reflective in the infrared wave lenghts. However, during the month of August alfalfa fields present a denser and a greener surface than cotton fields. Consequently alfalfa has a smaller spectral ratio than cotton.

The unknown land use class consists of greatly frangmented fields of various irrigated crops intermixed with wheat fields, bare soil, trees, and shurbs. Due to the small size of the fields, the resolution was poor and the separation was not feasible. The variability in the spectral signatures of this land use class is also reflected in the histograms, which are dinstinctly bimodal. The spectral classes 4,5 and 9 were assigned to this land use class.

Corn fields covered a large area in the irrigated bottomland. Two spectral classes were associated with the cornfields: class 10 and class 12. As it can be seen in tables 2 and 4, the two classes have similar characteristics and the histograms of the land use class are unimodal.

At the time of the spectral recording by ERTS-1, corn was approaching maturity and irrigation was not as intensive as in alfalfa and cotton. Thus, the relative reflectance of corn fields in the infrared region was somewhat lower than that of the other two crops.

Spectral class 10 has lower ratio than class 12. The difference may be attributed to variations in irrigation and in the maturity stage of the crop.

The land use class trees and shurbs covers the surrounding hills of the Kopais plain. This land use class is characterized by brocken forest and shrub vegetation, growing on soils developed on tertiary and quaternary deposits as well as on soils developed on limestone. The depth of the soil is adequate for the growth of vegetation. Its moisture regime, however, is not favorable. In small scattered areas, the native vegetation has been cleared out and the land is used for dry farming olive groves and vineyards. A number of these farms have been abandoned.

The spectral classes, which were associated with this land use class, were the 11,13 and 14. These three classes differ in their total reflectivities but the reflected energy is about equally distributed between the visible and the infrared range in all of them. Thus, the spectral ratios approach unity, a value which lies between that of the bare soil and the green vegetation.

Water is characterized by low reflectivity, especially in the infrared range. Spectral class 15 was therefore the apprortiate one to be assigned to water, which was in complete agreement with ground data.

Training and test fields were selected in the computer print of the spectral classes. The fields were selected on the basis of ground truth information. The training class performance is shown in table 5.

The minimum size of the fields which could be classified and mapped as distinct land use classes was that of 3 to 4 hectares. Below this size limit the fields were classified into the unknown land use class.

Table 5. Training class performance for the Kopais Plain.

Class	No. of samples	Percent correct classification	Corn	Wheat	Alfalfa	Trees	Cotton	Unknown	Soil	Er. Soil	Threshold
1. Corn	468	96.8	453	0	0	0	1	14	0	0	0
2. Wheat	248	91.1	0	226	0	0	0	1	20	0	1
3. Alfalfa	98	94.9	0	0	93	0	2	3	0	0	0
4. Trees-shrubs	345	98.0	0	0	0	338	0	0	0	0	7
5. Cotton	75	97.3	0	0	0	0	73	0	0	0	0
6. Unknown	84	98.8	0	0	0	0	1	83	0	0	0
7. Soil	110	95.5	0	0	0	4	0	0	105	1	0
8. Eroded Soil	136	97.1	0	0	0	0	0	0	0	132	4
Total	1564		453	226	93	342	77	101	125	133	12

Over all Performance (1503/1564) = 96.1%
Average Performance by class (769.4/8) = 96.2%

Table 6. Approximate accuracy of the land use map

Land use class	% Classified correctly	Incorrect classifications
1. Corn	90	shrubs as corn
2. Wheat	95	Dry weeds as wheat
3. Alfalfa	90	Cotton as alfalfa
4. Trees and shrubs	90	Vine, alfaffa as shrubs
5. Cotton	90	Alfalfa, vines
6. Unknown	100	-
7. Soil and rocks	100	-
8. Eroded soil	100	-

Land Use Mapping

The computer was instructed to print a land use map, in which the nine classes were represented by alphanumeric symbols. The scale of the map was about 1:22,000. A threshold of 0,5%, which corresponded mainly to residential areas, was used in the process of grouping spectral features into land use classes. The map was then checked against detailed ground truth information. Its approximate accuracy is shown in table 6.

The data in table 6 suggest that the accuracy of the land use classification and mapping was satisfactory.

The high accuracy of the classes unknown, soil-rocks and eroded soils can be explained by the broadness of feature characteristics that they include.

CONCLUSIONS AND SUMMARY

Photographic and digital imagery of Central Greece and Eastern Paloponnese were analyzed.

On the basis of information extracted from black and white, false color composite photographic imagery and spatial information the following land use classes were recognized and mapped.

a. Forests: dense and thin stands of fir, austrian pine and halepo pine.
b. Shrubs and idle land: dense shrubs, thin shrubs and rocky idle lands.
c. Agricultural lands: well irrigated and marginally irrigated crops, winter farmland, olive groves and vineyards.

The accuracy of the above maps was satisfactory.

Photographic imagery and photographs printed from the digital display were used to recognize and map recent alluvial soils, tertiary soils, eroded residual soils, wet soils,and saline soils.

False color composites made throught additive process from RBV and MSS 1:1,000,000 scale photographic images were used to indetify and map agricultural forest and range site evaluation classes, based on the water supplying capability of the soil.

Digital data from the Kopais plain were analyzed at LARS by the use of LARSYSAA computer program. Fifteen spectral classes were assigned to respective detailed crop and semidetailed soil classes. Alphanumeric computer maps of about 1:22,000 scale were printed, showing the distribution of these nine classes. These maps provide information of the degree of proper utilization of land resources in the studied area.

The feature recognition patterns, which were developed in this investigation, are strongly influenced by the local ecological, spatial and land parameters. Thus the results found and the techniques proposed in this report may have applications to areas of ecological, land and agricultural conditions similar to those of Southeastern Greece.

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ESTIMASION OF COST BENEFITS

Practical applications.

Land use and ecological site maps of about 1:200.000 scale can be prepared from black and white and false color composit ERTS imagery. Two data collection dates would be necessary for Eastern Mediterranean, one in April and one in August. The accuracy of the maps would be about 80-90%.

Digital data can be used for detailed crop indentification and mapping with an accuracy better than 90%. August would be the best data collection time.

Digital data can also be used for soil reconnaisance.

Agencies which would use the results of this investigation are the Agricultural and Forest Service and the Departments of Coordination and Planning.

Decisions and actions affected by the information of the ERTS project are: a) The selection of sites for reforestation b) Soil conservation and irrigation practices c) agricultural policy and trade of agricultural products.

Cost benefits.

Due to the lack of sufficient data not accurate estimate of cost benefits can be made. On a rough estimate the information received from ERTS-1 costs about ten times less than that obtained by conventional methods.